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Transition Strategies for Post-CRP Certified Organic Grain Production

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Abstract

Post-Conservation Reserve Program (CRP) land may provide an excellent opportunity to satisfy certified organic crop production requirements. However, conversion of CRP or long-term pastureland to certified organic production will require tillage because the use of herbicides is prohibited in organic production. Our objectives were to evaluate stand establishment, weed competition, yield, and grain quality for soybean (*Glycine max* [L.] Merr.), corn (*Zea mays* L.), and oat (*Avena sativa* L.) planted following primary tillage of bromegrass (*Bromus inermis* L.) and alfalfa (*Medicago sativa* L.) sod in south-central Iowa. Primary tillage treatments were fall moldboard plowing, fall tillage with a Kverneland® plow, fall and spring tillage with a Howard Rotavator®, and spring moldboard plowing. Type of primary tillage did not affect first-crop soybean yield in the first year of the study, but first-crop soybean yields were greatest with spring moldboard plowing in the second year's evaluation. Corn yields in the second year plots were greater for both the fall and spring moldboard plow treatments than for the fall/spring rotary tillage treatment. Rotary hoeing reduced soybean stand more than expected (~40%) in the first year, but differences among primary tillage treatments were not significant. In the second year, the rotary tillage treatment had significantly lower soybean stand, possibly because of surface crusting. There were some significant differences in grass and broadleaf weed populations in the corn and soybean each year, but overall weed control was considered sufficient. Insect pressure from corn borer (*Ostrinia nubilalis* [Hübner]) and bean leaf beetle (*Cerotoma trifurcata* [Forster]) was below economic threshold levels. Crop yields exceeded the county average each year, suggesting that weed and insect pest competition were negligible. We conclude that organic grain crops can be successfully produced following CRP or other long-term hay/pasture crops regardless of the primary tillage method used to till the sod.

Introduction

Organic farming has increased to an $8 billion industry in the U.S. and continues to expand at a rate of approximately 20% per year (5). In Iowa alone, land under organic management increased from 13,000 acres in 1995 to 120,000 acres in 1999 (9). Certified organic crops can command up to a 300% premium over conventionally raised crops (4), and thus economic incentives are driving many transition decisions. Organic certification requires that prohibited synthetic substances (fertilizers and pesticides) not be applied for at least 36 months prior to harvest (10,17). Options for transitioning Conservation Reserve Program (CRP) land (20) include certified organic crop production, which has increased throughout the Midwest (3). For CRP lands in Iowa that are not treated with synthetic fertilizers or pesticides, organic certification could be attained without the typical three-year transition period from conventional production (10).

Previous studies have shown soil quality benefits obtained with CRP investment can be maintained by using herbicides and no-till practices to return the land to crop production (12). However, synthetic herbicides are prohibited for use in certified organic production so farmers must rely solely on tillage for transition of CRP land into certified organic fields. Determining the best primary tillage strategy for transitioning CRP into organic crop production is important because tillage practices typically affect weed populations and subsequent yields (7,8) as well as runoff, sediment transport, and nutrient losses. Furthermore, weed management and soil fertility are consistently two of the most important management issues for organic farmers (19).

Field studies evaluating CRP transition are also needed to understand potential effects of other pests (e.g., insects, diseases, nematodes). For example, grassland herbivores in CRP land may switch hosts and colonize agronomic species, impacting yields and subsequent cropping practices (2). Our objective for this study was to quantify first-year response of corn and soybean to four primary tillage options for converting CRP land to organic production. Stand establishment, weed and insect populations, yield and grain quality were evaluated.

Materials and Methods

1999 Field Season - Site 1. Our study was initiated in October 1998 within a 5-yr-old bromegrass and alfalfa field located at the Iowa State University McNay Research and Demonstration Farm near Chariton, Iowa. Because of the unavailability of CRP land at the McNay Farm, due to the restriction against government farms enrolling in the CRP program, we chose a site most representative of CRP land in the area. Land enrolled as CRP in Lucas County is typically minimally managed, bromegrass-based land with 2 to 9% slope (*personal communication*, J. Secor, 2001). Soils on the site chosen to simulate local CRP land were Arispe (fine, smectitic, mesic Aquic Argiudolls) silty clay loam (~75% of the area) and Grundy (fine, smectitic, mesic Aquertic Argiudolls) silty clay loam with 2 to 5% slope. Four primary tillage treatments (fall moldboard plowing; fall tillage with a Kverneland plow; fall and spring tillage with a Howard Rotavator; and spring moldboard plowing) were evaluated in 32 plots (30 x 60 ft) using a randomized complete block design with eight replications. A 15-ft border was established around each plot to permit turning of machinery. The Kverneland plow was evaluated since very little research information was available in the U.S. for this Norwegian tillage tool. Local farmer experience suggested that this plow was more effective in burying surface applied manure, crop residue, and weed seed than U.S. moldboard plows because each furrow was completely inverted. The Kverneland plow was also more adjustable than standard U.S. moldboard plows in furrow width (12 to 20 inches) and bottom number. Farmer experience also suggested that draft requirements were lower, but we were not able to determine this effect in small research plots. The Howard Rotavator was chosen because it tilled the soil, incorporated surface residues, and prepared a seedbed in one operation.

The fall tillage was completed by 14 October 1998 and winter rye (*Secale cereale* L.) was broadcast at a rate of 70 lb/acre on the tilled plots with a three-point mounted spreader. Rye was planted to minimize soil erosion and mitigate weed growth in the spring. Beef cattle manure was applied at a rate of 2 tons/acre in the spring (Table 1). The Howard Rotavator plots were tilled again in the spring, and the moldboard treatment was imposed on 4 May 1999. All plots were disked twice (4 and 28 May) to incorporate the manure and kill the rye and cultipacked on 28 May to smooth the seedbed. A tofu-type soybean ('IA2034'), was planted at a rate of 175,000 seeds/acre on 28 May. Plots were rotary-hoed for weed control on 6 and 18 June, and row-cultivated on 24 June, 7 July, and 15 July. Large or staining weeds growing above the canopy were removed by hand on 15 August, per local organic soybean grower practices.

Table 1. Beef cattle manure analysis for soybean (1999) and corn (2000) production on simulated CRP land conversion at McNay Memorial Research and Demonstration Farm, Chariton, IA.

Total N (%)	P_2O_5 (%)	K_2O (%)	Total C (%)	Solids (%)
2.26	0.50	3.49	36	31

Stand counts were taken on 21 June (24 days after planting [DAP]). Weed populations were determined for each plot by counting all grass and broadleaf species in three randomly placed 10.8-ft^2 quadrants on 21 June and 26 August. Plants were visually sampled for insect pests on 21 June and 26 August. More extensive pest sampling occurred in 2000 when damaging soybean pests were reported in Iowa (13). Soybean plots were harvested on 7 October.

Post-harvest soil samples were taken in November 1999 by compositing five 8-inch-deep soil cores collected from each plot. Field-moist samples were pushed through a 0.31-inch-diameter sieve and soil water content was determined gravimetrically by oven drying overnight at 221°F. A sub-sample of the field-moist soil was pushed through a No. 10 (2-mm-diameter) sieve, air dried, and stored at room temperature prior to soil analysis. Field-moist soil sub-samples were extracted with 2 M KCl, and inorganic N ([NO_3 +NO2] and NH4) in the filtrate was determined using flow injection technology (Lachat Instruments, Milwaukee, WI). Soil organic C, total N, pH, EC, soil-test P (Bray P1), and exchangeable K, Ca, and Mg were determined using air-dried samples. Total organic C (after removal of carbonates with 1 M H2SO4) and total N were measured using dry combustion methods in a Carlo-Erba NA1500 NCS elemental analyzer (Haake Buchler Instruments, Paterson, NJ). Soil pH and EC were measured using a 1:2 soil-to-solution ratio. Phosphorous concentrations were measured colorimetrically using ascorbic acid-ammonium molybdate reagents. Extracted cations were measured using atomic absorption spectrophotometry.

2000 Field Season - Site 2. A second site on the research farm, with similar bromegrass and alfalfa vegetation, was chosen for the 2000 field season evaluation of CRP tillage conversion options. This site had approximately equal amounts of Grundy silty clay loam with 2 to 5% slope and Edina (fine smectitic, mesic Typic Argialbolls) silt loam in depressions with 0 to 1% slope. Plot size, borders, and tillage treatments were the same as in 1999, but the experiment was expanded to include corn and oat plus red clover (*Trifolium pratense* L.) as the initial crops planted into simulated CRP land. The additional crops were added to comply with organic certification requirements for a minimal three-crop rotation (10). Each crop by tillage treatment was replicated four times in a 48-plot randomized complete block design.

Fall tillage operations were completed between 15 and 21 October 1999 and winter rye was sown on 25 October in soybean-designated plots. Spring moldboard plowing was completed on 16 March 2000. The plots destined to be oat and red clover were disked twice on 17 March and sown with 2 bu/acre of ‘Jerry’ oat and 12 lb/acre ‘Cherokee’ red clover on 25 March. Stockpiled cattle manure from the first-year study was applied to the corn plots at a rate of 4.5 tons/acre and incorporated by disk on 4 April. Manure was not applied to soybean plots in an effort to conserve a limited manure supply and determine soybean productivity without additional inputs. Winter rye in the soybean plots was disked on 14 April. Corn and soybean plots assigned to the fall moldboard, spring moldboard, and Kverneland plow treatments were disked twice while the rotavated plots were tilled again on 16 May with a Howard Rotavator.

Pioneer Brand ‘34W67’ corn and ‘9305’ soybean were planted on 16 May at rates of 30,000 and 175,000 seeds/acre, respectively. Corn plots were rotary-hoed for weed control on 23 May and 1 June and row-cultivated on 12 and 19 June. Soybean plots were rotary-hoed for weed control on 6 and 13 June, row-cultivated on 20 June and 10 July, and hand-weeded on 21 and 28 July. Oat plots were harvested on 14 July and straw was baled. Corn and soybean plots were harvested on 8 October.

Stand counts in corn and soybean plots were taken on 1 and 9 June (16 and 24 DAP). Weed counts (three 10.8-ft^2 quadrants per plot) were also taken in the corn and soybean plots on 9 June. The effect of fall or spring plowing on destroying insect pests or over-wintering sites was investigated through insect monitoring. Bean leaf beetle populations were determined by sweeping each soybean plot 20 times with a 15-inch diameter net (*personal communication*, Dr. W. F. Lam, 2000) on 7 July. Bean leaf beetles over-winter in Iowa and carry the bean pod mottle virus, which stains the soybean seed coat and causes a significant reduction in returns (13). Corn borer levels were measured by removing three random corn whorls per plot on 7 July and determining the number of feeding holes. Soybean cyst nematode (*Heterodera glycines*) populations were determined by collecting three 6-inch soil cores per soybean plot and analyzing for presence of eggs on 5 October. Corn and soybean grain were analyzed for protein, carbohydrates, fiber, and oil by the Iowa State University Grain Quality Laboratory in the Department of Food Science. An 8.8-oz soybean sample from each plot was also evaluated to determine percentage of stained seed (soybean with a tan, brown, or mottled appearance). Post-harvest soil samples were also taken in October 2000. Sample processing and laboratory analyses were carried out as described for Site 1.

Experimental data were analyzed for statistical differences using StatView (15). Least significant difference (LSD) values were calculated when the F values for treatment comparisons were significant at $P = 0.05$.

Results and Discussion

Four primary tillage strategies for returning CRP land to crop production were evaluated because the most common conversion practice (using synthetic herbicides to kill the vegetation and control subsequent weeds [11]) is prohibited if the land is to be certified for organic production. Fall and spring moldboard plowing were evaluated as traditional methods for tilling sod crops. Typically, organic farmers in the Midwest will plow in the fall prior to conversion rather than in spring because of competition with other spring field activities such as compost or manure application and planting. Many farmers believe that fall plowing leads to a more friable surface by exposing the soil to freezing and thawing cycles throughout the winter. Furthermore, farmers who are risk-averse plow in the fall to avoid spring rains that would prevent plowing.

Synchronization of nutrient availability and uptake is a justification for spring plowing since organic cropping systems rely solely on nutrients derived through decomposition of biologically active organic matter or the addition of organic amendments. In addition to optimizing nutrient-use efficiency, spring plowing allows for the maintenance of a vegetative cover throughout winter which can help prevent soil erosion and minimize loss of soil nutrients through surface runoff and leaching (1,6).

Crop Response - 1999. Weather conditions in Spring of 1999 and 2000 were suitable for land preparation, sod degradation, and crop production (Table 2). Plant populations were not significantly different across the four tillage treatments at 24 DAP (Table 3), although the two rotary hoe cultivations presumably reduced the stand more than expected. Soybean populations were approximately 40% less than the planting rate (175,000 seeds/acre) for all tillage treatments. Grass weeds (primarily *Setaria* sp.) were the dominant weed type on 21 June (24 DAP), with significantly higher populations in the Howard Rotavator treatment than in the others. The higher weed counts likely reflected the shallower, non-inversion tillage associated with the Howard Rotavator. There were no significant early-season differences among tillage treatments for broadleaf weed populations (Table 3) and neither broadleaf nor grass weed populations showed any significant differences among primary tillage treatments when sampled in late August, near the end of the growing season. Soybean insect pests were not observed in 1999 (data not shown). There were no significant differences in soybean seed yield among tillage treatments, but the 43 bu/acre yield average exceeded the 1999 Lucas County average of 38 bu/acre (14). Soybean grain quality exceeded minimum levels required for food-grade soybean, with an average protein content of 42.2%.

Table 2. Total precipitation and average temperature at McNay Memorial Research and Demonstration Farm, Chariton, IA, 1999 and 2000.

	1999 Precipitation (inches)	**1999 Temperature** (°F)	**2000 Precipitation** (inches)	**2000 Temperature** (°F)
Jan	0.92	20.4	0.55	26.0
Feb	1.25	34.7	1.51	35.9
Mar	0.88	36.6	0.57	43.8
Apr	5.22	49.6	1.97	51.0
May	5.34	59.8	1.58	63.8
June	4.99	69.2	8.1	68.2
July	4.7	70.8	4.22	73.1
Aug	3.88	71.8	2.7	75.0
Sept	2.24	62.2	4.22	66.0
Oct	1.34	52.6	1.5	56.4
Nov	1.41	46.8	1.37	33.4
Dec	0.45	28.8	1.39	11.9

Table 3. Primary tillage effects on stand establishment, weed populations, yield, and protein content of soybean planted into simulated CRP land in 1999.

Tillage treatment	**Plant population**	**Grassy weeds**		**Broadleaf weeds**		**Grain yield**	**Grain protein**
	21 June	21 June	26 August	21 June	26 August		
	---- plants/acre (x1000) ----					bu/acre	%
Fall moldboard	95	4.0	3.6	4.4	9.0	41	42.1
Spring moldboard	104	4.0	5.1	2.2	5.7	43	42.7
Kverneland	102	5.8	1.3	4.3	6.8	42	41.8
Howard Rotavator	99	13.1	1.2	3.2	3.4	45	42.4
$LSD_{(0.05)}$	NS	6.2	NS	NS	NS	NS	NS

Soil-test - 1999. Initial soil samples collected for Site 1 in November 1998 had an average organic C concentration of 2.6% and P and K concentrations of 8 and 116 ppm, respectively. Soil-test ratings based on these values were low for P and medium for K (18) so manure was applied as a certified organic P and K source for soybean production. Following soybean harvest, total organic C and total N ranged from 2.6 to 2.8 and 0.23 to 0.25%, respectively (Table 4). Soil fertility was above average, with extractable P and K values in the high soil-test range and soil nitrate-N concentrations averaging 16 ppm across the treatments. Undoubtedly, this reflected residual availability of spring manure application. Soil pH averaged 5.6 and none of the soil-test measures showed significant differences among the tillage treatments.

Table 4. Post-harvest soil-test values for the 0-8 inch depth at Site 1 in November 1999.

Tillage treatment	Organic C	Total N	NO_3-N	NO_3 + NH_4	P	K	Ca	Mg	pH
	---- % ----		---- ppm ----						
Fall moldboard	2.62	0.23	16	21	30	162	3891	665	5.6
Spring moldboard	2.63	0.23	15	21	26	151	3852	664	5.6
Kverneland	2.79	0.24	15	20	25	139	3691	583	5.5
Howard Rotavator	2.83	0.25	16	21	32	141	3737	614	5.6
$LSD_{(0.05)}$	NS	NS	NS	NS	NS	NS	NS	NS	NS

Crop Response - 2000. Primary tillage of the grass/alfalfa sod with the Howard Rotavator resulted in significantly lower soybean populations 16 and 24 DAP in 2000 (Table 5). This may have been due to soil crusting as a result of pulverizing the soil with the rotary tillers. While creating effective soil-to-seed contact, this method reduces soil aggregation and may result in soil crusting following intensive rainfall events (16). The slightly lower plant population may have contributed to lower grain yield. Soybean plant population following spring moldboard tillage was significantly greater than that for the Howard Rotavator. This is likely to have contributed to the significantly greater soybean yield for the spring moldboard treatment. Grass populations 24 DAP in soybean plots showed no significant differences (Table 5), but use of the Howard Rotavator resulted in significantly fewer broadleaf weeds. Overall, organic soybean yields averaged 49 bu/acre and were greater than the 2000 Lucas County average of 39 bu/acre for conventionally produced soybean (14). There were no significant differences in soybean protein content among tillage treatments in 2000 (Table 5), although the levels were approximately 3.8% lower than in 1999 (Table 3). The other soybean quality factors (oil, carbohydrate, and fiber content) showed no significant treatment response (data not shown).

Table 5. Primary tillage effects on stand establishment, weed populations, yield, and protein content of soybean planted into simulated CRP land in 2000.

Tillage treatment	Plant population		Weed population (24 DAP†)		Grain yield	Grain protein
	1 June (16 DAP)	9 June (24 DAP)	Grasses	Broadleaf		
	---- plants/acre (x1000) ----				bu/acre	%
Fall moldboard	141	156	5	11	49	38.6
Spring moldboard	158	162	9	10	52	38.7
Kverneland	140	155	7	11	48	38.3
Howard Rotavator	93	130	14	4	47	38.5
$LSD_{(0.05)}$	41	24	NS	6	3	NS

† DAP = days after planting

There were no significant differences in corn populations among the tillage treatments in 2000 (Table 6). Compared to the 2000 Lucas County average corn yield of 130 bu/acre (14), the 181 bu/acre average yield for organic corn was excellent. There were no significant differences among tillage treatments for broadleaf weeds 24 DAP, but a significantly higher population of grassy weeds was correlated with use of the Howard Rotavator (Table 6). Corn grain protein in 2000 (Table 6) showed a significant response to primary tillage with grain from the Howard Rotavator treatment having a significantly lower protein content than the Kverneland plow treatment. As with soybean, the other grain quality factors (oil, starch, and density) showed no significant treatment response (data not shown).

Table 6. Primary tillage effects on stand establishment, weed populations, yield, and protein content of corn planted into simulated CRP land in 2000.

Tillage treatment	**Plant population**		**Weed population (24 DAP†)**		**Grain yield**	**Grain protein**
	1 June	9 June	Grasses	Broadleaf		
	--- plants/acre (x1000) ----				bu/acre	%
Fall moldboard	23	23	6	11	188	8.3
Spring moldboard	23	23	6	16	193	8.2
Kverneland	21	22	9	9	177	8.4
Howard Rotavator	20	22	21	8	166	8.0
LSD$_{(0.05)}$	NS	NS	10	NS	19	0.2

† DAP = days after planting

There was no significant difference in oat yield among the tillage treatments (Table 7), but grain from the Howard Rotavator treatment did have a significantly higher test weight than those from the Kverneland plow treatment.

Table 7. Primary tillage effects on yield and test weight of oat planted into simulated CRP land in 2000.

Tillage treatment	**Grain yield** (bu/acre)	**Test weight** (lb/bu)
Fall moldboard	61	35.8
Spring moldboard	62	35.9
Kverneland	55	35.4
Howard Rotavator	54	36.2
LSD$_{(0.05)}$	NS	0.5

Early season bean leaf beetle populations were very low in 2000. However, 16% of the seed exhibited staining, which would downgrade these seed from premium priced organic tofu soybeans to organic feed soybeans. Corn borers were not detected in any of the plots during peak population periods in 2000 and there were no soybean cyst nematode eggs detected in the post-harvest soil samples (data not shown).

Soil-test - 2000. Pre-tillage soil-test data collected from each of the plots in October 1999 showed very low soil-test P (4 ppm) and NO_3-N (3 ppm) concentrations, presumably reflecting cumulative nutrient removal effects of the five-year alfalfa/bromegrass hay and pasture crops grown on this simulated CRP site. Total organic C and N concentrations (2.43 and 0.22%, respectively) were slightly lower at Site 2 than at Site 1. The initial exchangeable K concentration (124 ppm) was similar to that at Site 1 (116 ppm), with both being interpreted as medium soil-test levels (18). Soil pH averaged 6.4, almost a full unit higher than the 5.6 at Site 1. There were no significant differences among tillage treatments for any of the soil-test parameters.

Post-harvest soil-test P showed the effects of the 2000 manure application, averaging 37 ppm or nearly an order of magnitude higher than in the pre-tillage samples. The average total organic C and N concentrations (2.60 and 0.23% respectively) were also slightly higher in post-harvest than pre-tillage samples. However, unlike Site 1 where post-harvest soil samples showed a 32 ppm increase in exchangeable K, samples from Site 2 decreased by 18 ppm. Presumably this occurred because only one-third of the plots (those planted to corn) received manure in 2000, whereas all soybean plots received manure in 1999. Among the tillage treatments, total organic C, extractable P, and exchangeable K were all significantly higher in the Howard Rotavator plots than in the other treatments (Table 8), probably because the depth of tillage was less and therefore there was a smaller dilution effect.

Table 8. Post-harvest soil-test values for the 0- to 8-inch depth at Site 2 in November 2000.

Tillage treatment	Organic C	Total N	NO_3-N	NO_3 + NH_4	P	K	Ca	Mg	pH
	---- % ----		---- ppm ----						
Fall moldboard	2.52	0.23	11	13	27	90	2823	274	6.2
Spring moldboard	2.48	0.22	10	13	36	104	2996	273	6.4
Kverneland	2.66	0.23	12	14	37	106	3106	259	6.4
Howard Rotavator	2.73	0.24	13	16	48	124	3135	261	6.4
$LSD_{(0.05)}$	0.16	NS	NS	NS	15	19	NS	NS	NS

Summary and Conclusions

Two simulated CRP sites were selected for this experiment in order to examine conversion to certified organic crop production using accepted tillage treatments in place of prohibited herbicides. Continuation of this experiment under a long-term rotation of soybean-oat/red clover-corn at Site 2 will quantify crop performance and soil changes on converted CRP land. Results of our two years of simulated CRP conversion showed there was no statistical yield difference due to primary tillage method in Site 1, while at Site 2, the spring moldboard plowing resulted in significantly higher soybean yield. At Site 2, numerically higher corn and oat yields were obtained in spring-plowed plots, although the agronomic differences were slight (i.e., spring and fall plow corn yields were significantly greater than with the Howard Rotavator). The subtle increase associated with spring plowing was presumably at least partially related to the release of stored nutrients from the soil that had been in a bromegrass and alfalfa hay/pasture for at least 5 years prior to the conversion. A few stand establishment, weed control, insect, and grain protein differences were noted, but there was no consistent crop production advantage for any of the primary tillage treatments. Rotary hoeing apparently resulted in greater soybean loss than expected at Site 1, since stand counts 24 DAP were approximately 40% lower than the planting rate (175,000 seeds/acre). Pre- and post-harvest soil-test P values were responsive to manure application, but we observed few meaningful differences due to the primary tillage method that was used to convert simulated CRP land to organic crop production. We conclude that the astute land manager can use any of the four tillage strategies we evaluated to successfully convert CRP or similar long-term hay and pastureland into an organic grain production site.

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